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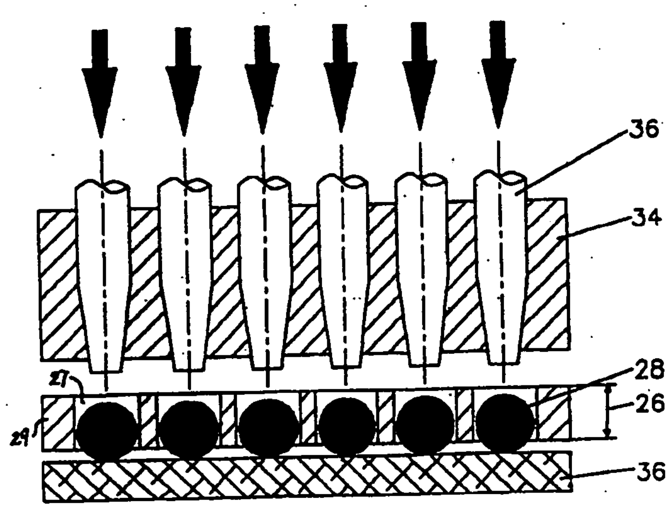
(54) Title: FLUXLESS LASER REFLOW WITH TEMPLATE FOR SOLDER BALLS OF BGA PACKAGING



(57) Abstract

A system of solder ball (28) placement and fluxless laser reflow on BGA packaging comprising means for template alignment, means for solder ball placement and a laser head. The template (29) is aligned with connection pads located on the surface of the substrate without flux. The aligned template allows accurate guiding of the balls onto the pads by the ball placement means. One ball is dropped into each hole (27) in the template directly onto the pads in the absence of flux. The solder balls positioned on the pads are then exposed to a laser via the laser head (36), resulting in the rapid melting of the solder balls directly onto the substrate pads. The melted balls are then allowed to cool rapidly. The present invention is preferably practiced on pads made from gold. The preferred condition for reflow is under nitrogen environment. Other types of pads composed of materials which are inert, do not oxidize readily in air and compatible with the solder ball reflow process are also compatible with the system according to the present invention.

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FLUXLESS LASER REFLOW WITH TEMPLATE FOR SOLDER BALLS OF BGA PACKAGING

FIELD OF THE INVENTION

The present invention relates to the use of soldering in the electrical connection between an IC device and a printed circuit board. In particular, the present invention relates to the use of laser technology for the reflowing of solder balls on a ball grid array (BGA) device.

BACKGROUND OF THE INVENTION

Ball grid array (BGA) packaging of integrated circuit (IC) devices is gaining increasing importance in IC device production. In BGA packaging, the IC chip is commonly mounted on a copper substrate with copper or gold pads, whereon flux is applied followed by the placement of solder balls. The solder balls are then soldered onto the pads in a reflow oven. Flux contains activators which facilitates the soldering or reflow process of the solder balls onto the copper pads. Due to the instability of copper in the presence of oxygen in the air, copper oxide is often found on the surface of the copper pads, which prevents proper soldering unless flux is present to remove copper oxide and react with the solder ball during the reflow process.

The conventional method of ball placement is to use a vacuum suction head with the appropriate array of suction holes to pick up the soldering balls. The balls sucked up in the proper array onto the head are then

lowered onto a substrate with pre-applied flux. This BGA assembly can then be conveyed to the reflow oven for soldering of the solder balls.

Current trend in IC chip production is for greater IC density per chip. The higher the IC density, the greater the number of interconnects required on the same chip size. Therefore, there has been a demand for BGA packages with higher density pads and solder balls. In these high density BGA packages, the number of interconnecting pads per chip can be as high as 1,000 to 2,000, compared to a low density BGA package of below 400 pads per chip for the same surface area. For high density packages above 400 pads per chip, the pitch (distance between two solder balls) and solder ball size have to be reduced accordingly. For example, a low density BGA configuration of below 400 pads per chip with a pad size of 25 mil. and pitch of 50 mil. can use solder balls of 30 mil. diameter. In the case of high density BGA configurations for example with pads of 10 mil. size and pitch of 20 mil., solder balls of 12 mil. diameter have to be used instead.

This reduced pitch and ball size poses a problem for the soldering process. The first problem is placement problem. Due to the very small size and light weight of the solder balls, even a minute air turbulence or a minor warpage of the substrate might result in a displacement of the ball position. Because of the fine pitch required in high density arrays, even a slight displacement may result in bridging, which is the mixing of two soldering balls to form a connection during the process of soldering in a reflow oven. Once bridging occurs, the entire package has to be rejected. Consequently, conventional method of ball placement using the vacuum suction head results is high rejection rates due to bridging. The second problem is in the

transfer of the packaging from the ball placement site to the reflow oven. Even if the solder balls were placed accurately, the movement necessary to transfer the packaging to the reflow oven would cause the balls to be displaced. In addition to the problems stated above, bulky and expensive equipment are required for the various steps including solder ball placement, reflowing in a reflow oven, and extensive washing with deionized water to remove any traces of residual flux (for water soluble flux). There is therefore a need to improve the packaging process by designing new concepts of ball placement and soldering which would prevent displacement of the solder balls and bridging while minimizing the amount of equipment involved in the process.

OBJECT OF THE INVENTION

It is an object of the present invention to provide an accurate method of solder ball placement in the packaging of BGA devices.

It is another object to reduce the occurrence of solder ball bridging in the reflowing process in BGA assembly line.

It is a further object to eliminate the necessity of a reflow oven in the soldering of solder balls on BGA devices.

It is yet another object to eliminate the steps of flux application and removal in the BGA device assembly process.

SUMMARY OF THE INVENTION

The present invention is a system of solder ball placement and fluxless laser reflow on BGA packaging comprising means for template alignment, means for solder ball placement and a laser head. A flux application step is eliminated and the template is aligned with connection pads located on the surface of the substrate without flux. The aligned template allows accurate guiding of the balls onto the pads by the ball placement means. One ball is dropped into each hole in the template directly onto the pads in the absence of flux. The solder balls positioned on the pads are then exposed to a laser via the laser head, resulting in the rapid melting of the solder balls directly onto the substrate pads. The melted balls are then allowed to cool rapidly. This fluxless laser reflow with template method improves the accuracy of the ball placement and alleviates the problem of ball bridging, while eliminating the use of the reflow oven and the cleaner, which are bulky and expensive equipment involved in the packaging of BGA devices. Packaging with pads made from material suitable for fluxless soldering is required for the practice of the present invention. These suitable materials are noble, and do not oxidize readily in air. Gold pads are preferred.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of the ball placement system according to the present invention.

Figure 2 is a schematic illustration of the laser reflow system according to the present invention.

Figure 3 is a schematic diagram to show the positioning of the matrix laser head for laser reflow of the solder ball.

Figure 4 is a flow diagram to illustrate the steps involved in the laser reflow process according to the present invention.

DESCRIPTION OF THE INVENTION

The present invention utilizes a combination of two separate techniques to achieve synergistically superior results in the packaging of high density BGA devices, while at the same time allows for the elimination of three major steps in the conventional BGA packaging method. The first technique involves the use of a template to guide the release and placement of the ball from a conventional ball sucking head. Once the balls are properly placed above the substrate and within the template, the second technique of laser reflow is used, which causes the melting and effective soldering of the solder balls. Using these two techniques in combination with the use of suitable pads, the two flux application and flux removal steps can be removed. The solder ball can be directly soldered onto the pads without the use of flux. In addition, the step of oven reflow is also eliminated. As a result, the time and bulky equipment required to complete the packaging process is substantially reduced.

Figure 1 shows a schematic illustration of the ball placement process according to the present invention. A template **22** of the high density array is placed directly over the substrate without any prior application of flux. A ball sucking head **24** with solder balls in position is aligned over the pads of the substrate, using the template as a guide. When the array in the ball sucking head is aligned with the array of the template, the vacuum on the ball sucking head is released, and the solder balls are discharged onto the substrate. The ball sucking head may be a conventional one commonly used in BGA packaging, with the array adapted for high density devices. The template can be a wire mesh with the mesh size of the required density.

The template may be made from any material which is heat tolerant such as stainless steel and aluminum. A preferred material is stainless steel. The wire of the mesh should be thick enough to prevent a solder ball from rolling over the wire. For example, for a solder ball with diameter of 12 mil, the thickness of the wire of the mesh, as indicated by reference numeral **26** of Figure 3, should be around 12 mil, to prevent the ball from rolling out of the cavity **27**. In addition, the inner area of the cavity should preferably be slightly larger than the cross-sectional area of the solder ball for ease of placement by the ball sucking head, and prevention of a ball getting easily attached to the wire mesh. A preferred area is 15-35% larger than the cross-sectional area of the solder ball. For the present invention, it is necessary for the pads to be made from a suitable metal or alloy which is noble such that the solder balls can be soldered directly onto the pads without the addition of flux. The preferred metal is gold.

Figure 2 illustrates how a matrix laser head is used to reflow the solder balls. The ball sucking head is moved away from the substrate after ball placement, and a laser head **30** is placed over the template and solder balls and melted rapidly under the laser beam to form intermetallic layer. Once the laser beam is switched off, the molten solder ball cools rapidly at a high cooling rate. The laser head is preferably of a gyroscope head or a matrix type head comprising of a series of optical fibers arranged in an identical array as the ball array. Lasers such as neodymium:yttrium-aluminum-garnet (Nd:YAG) laser is suitable for laser reflow. The laser reflow may be performed under normal ambient conditions, or it can be performed in a nitrogen environment. The duration and intensity of the exposure varies

with the different solder balls, and can be determined with routine experimentation.

Figure 3 shows the alignment of the optic fibers of the laser head with the solder balls **28** placed inside the cavities **27** of the template **29** above the substrate. The optical fibers are housed in a housing **34** which fixes the position of the optical fibers **36** to match the position of the pads and the solder balls. The wire mesh of the template has a height **26** approximately the same as the diameter of the solder balls.

Figure 4 is a flow diagram to show the process according to the present invention. The template is aligned directly with the substrate followed by ball placement with the ball sucking head **42**. Then a visual check **44** is preferably performed to ensure that the balls are placed properly, followed by laser reflow **46**. Steps **42-46** are preferably performed with the package stationary to minimize any disturbance to the balls once they are placed onto the substrate. After laser soldering, the package may be heated in a reflow oven or a hot plate **48** for a short time to smoothen and polish the surfaces of the soldered balls. The visual checking step is performed using a camera, for example a CCD (capacitor charge device) camera.

While the present invention has been described particularly with references to Figs 1 and 4, it should be understood that the figures are for illustration only and should not be taken as limitation on the invention. It is contemplated that many changes and modifications may be made by one of ordinary skill in the art without departing from the spirit and the scope of the invention described.

CLAIMS

I Claim:

1. A system of solder ball placement and fluxless laser reflow of ball grid array packaging of an IC chip with a substrate having an array of pads comprising :

means for template alignment having a template with an array of cavities matching said array of pads,

means for solder ball placement and

a laser module with a laser head adapted to send at least one laser beam onto said solder balls,

said system performing the sequential steps of :

aligning said cavities of said template with said array of pads;

aligning said means for solder ball placement with said substrate using said template as a guide so that an array of solder balls is aligned with said array of pads;

discharging said aligned solder balls onto said pads so that one solder ball is placed within each cavity of said template;

aligning said laser head with said substrate; and

discharging a laser beam directly onto said solder ball such that said solder balls are melted and soldered onto said pad without flux.

2. A system of solder ball placement and fluxless laser reflow according to claim 1 wherein said system further comprises a camera, and an

additional step of visual checking with said camera is performed after solder ball placement.

3. A system of solder ball placement and fluxless laser reflow of ball grid array packaging according to claim 1 wherein said laser head is a matrix laser head.

4. A system of solder ball placement and fluxless laser reflow of ball grid array packaging according to claim 1 wherein said laser head delivers a Nd:YAG laser beam.

5. A system of solder ball placement and fluxless laser reflow of ball grid array packaging according to claim 1 wherein said laser soldering step is performed under nitrogen environment.

6. A system for solder ball soldering according to any one of claims 1-5 wherein said system further comprises a heat plate, and an additional step of heat polishing of said solder balls is performed with said heat plate after said laser soldering step.

7. A system of laser reflow with template according to any one of claims 1-5 wherein said system further comprises a reflow oven, and an additional step of heat polishing of said solder balls is performed with said reflow oven after said laser soldering step.

8. A system of laser reflow with template according to any one of the preceding claims wherein said pad is made from gold.

9. An apparatus for solder ball placement of ball grid array packaging of an IC chip with a substrate having an array of pads for interconnection comprising :

means for template alignment having a template with an array of cavities matching said array of pads;

means for solder ball placement onto said pads without flux; and

a laser head adapted to send a laser beam onto said solder balls such that said solder balls are melted.

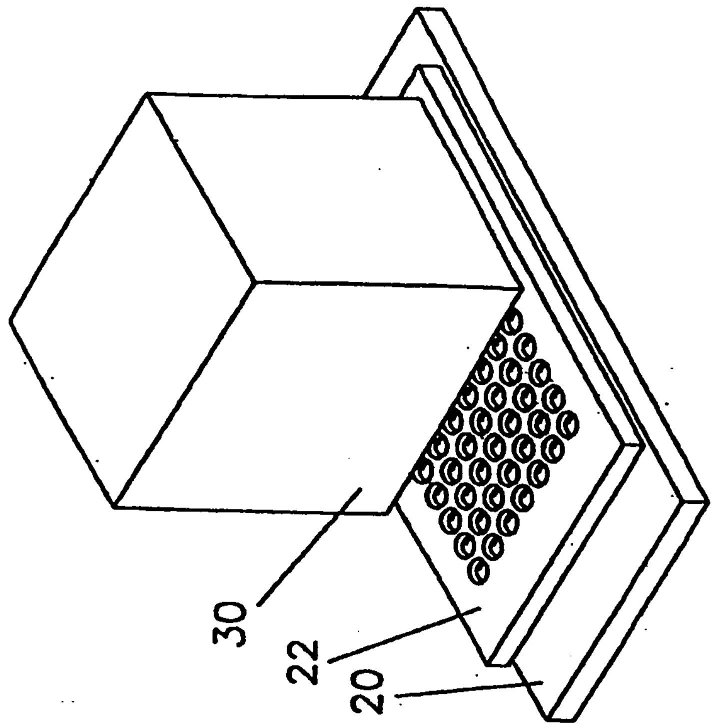

Fig. 2

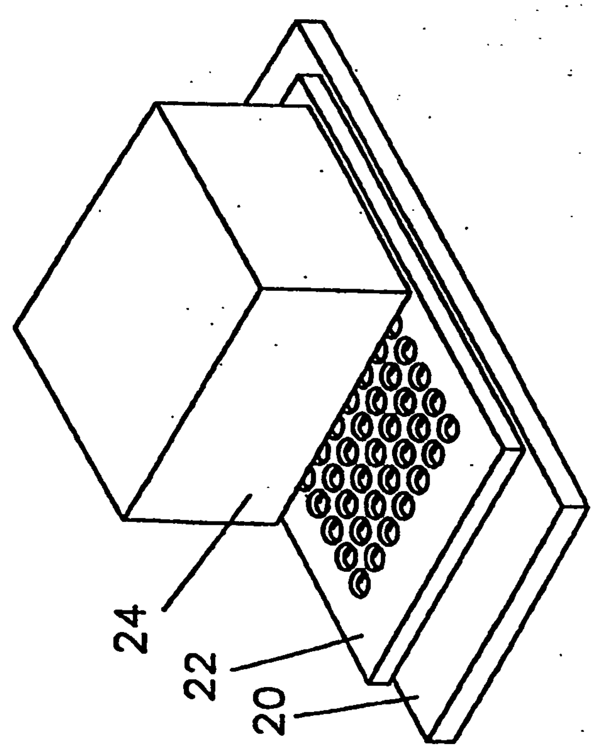

Fig. 1

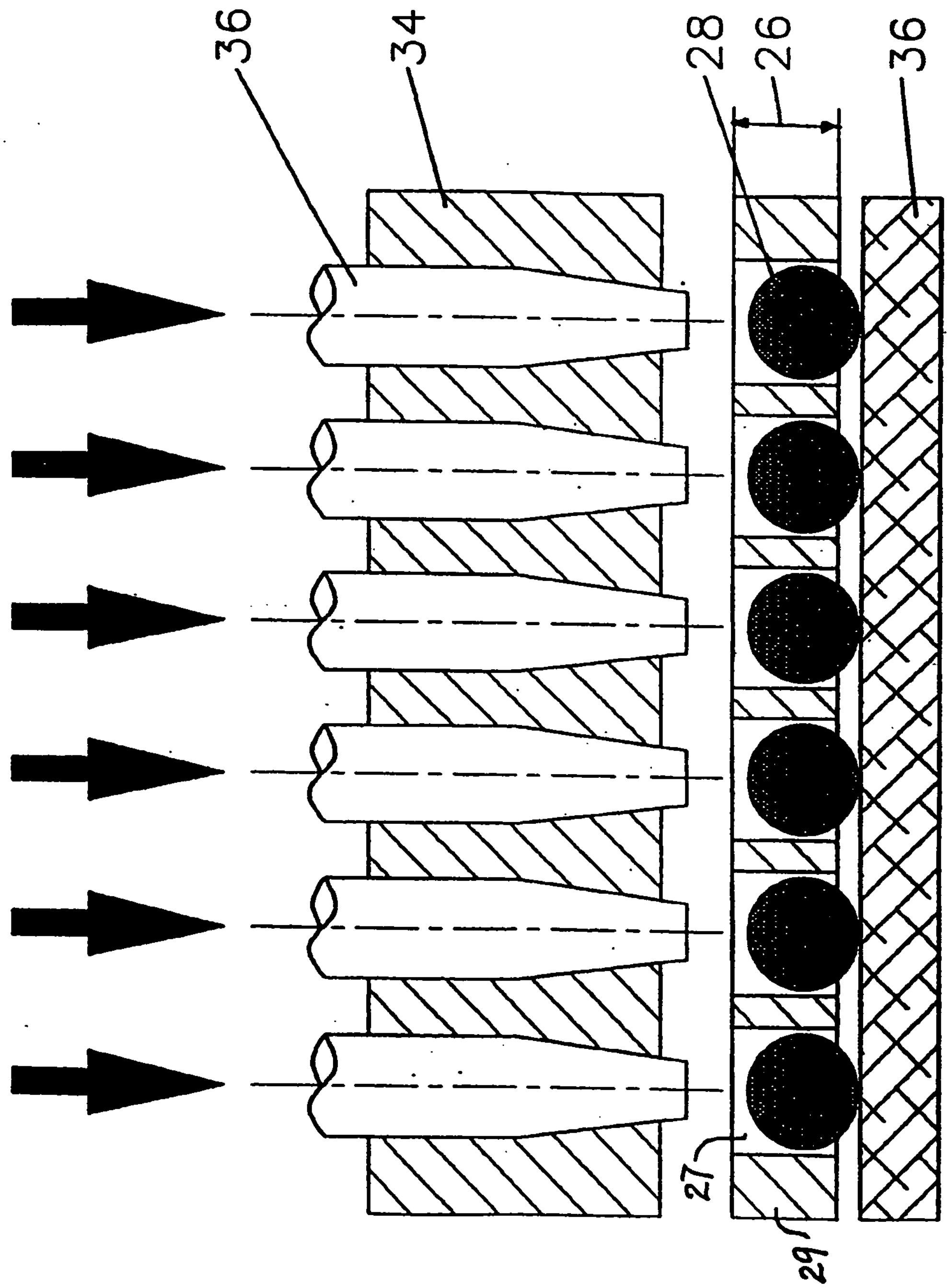

Fig. 3

42 BALL PLACEMENT

↓

44 VISUAL CHECK

↓

46 LASER REFLOW

↓

48 HEAT POLISHING

FIGURE 4

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/SG 98/00054

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: H05K 3/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : whole field

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC H05K 3/34

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT, JAPIO, INSPEC
Keywords : BGA, Ball Grid Array, laser, Template

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Recent Progress in Printed Circuit Board Technology, Berlin, Germany, 27-29 January 1997, "Solder Ball Bumping for Printed Circuit Boards" 176 PP Kasulke P et al	
Y	abstract	9
A	abstract	1
	Derwent Abstract Accession No. 96-281730/29, Class LO3M23, JP 08-118005 A (MATSUSHITA DENKI SANGYO KK) 14 May 1996	
Y	abstract	9
A	abstract	1

[X] Further documents are listed in the continuation of Box C

[ ] See patent family annex

* Special categories of cited documents:

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C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	1ST 1997 IEMT/IMC Symposium (IEEE cat. No. 97CH36056) pp 295-298 published Tokyo, Japan 1997 "High Density BGA substrates fabricated by Laser Technology "Hirakawa T et al whole document	
A	Solid State Technology, vol. 39, no. 9, pp. 120-122, 124, 127, 128 Penn Well Publishing USA September 1996 "Laser Drilling Speeds BGA packaging" Lizotte T et al whole document	
A	Proceedings of the Technical Program, National Electronic Packaging and Production Conference. NEPCON East 1994 pp. 336-343 published Stamford, CT, USA "An Overview of advancements in surface mount and fine pitch technology", Rua R whole document	